DElight

Daylighting / Electric Lighting Modeling in Buildings

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Overview

- DElight Requirements
- DElight Components
- Modeling Capabilities (Near Term)
- General Approach
- DElight Calculation Sequence
- Complex Fenestration Systems
- Software Implementation
- Issues
- Potential future enhancements

DElight Challenge

- There are sophisticated electric lighting modeling tools in the private sector, but not daylighting modeling tools. Why?
- Daylighting problem is much more complex
  - Complex external illuminated environment: sky, ground, objects
  - Complex fenestration system (CFS) apertures
- Modeling cannot be done in isolation from other building processes (electric lighting, thermal)

DElight Requirements

- Integrate with thermal analysis
- Integrate with electric lighting controls
- Fast
- NO requirement for rendering of a visual image

DElight Components

- Stand-alone, single-sky-condition, integrated daylight - electric light modeler
- Preprocessor generates Daylight Factors (DF) for multiple sky conditions
- Whole building analysis integration (e.g., Energy-10): Integrated thermal-loop analysis of lighting control system and subsequent lighting electric requirements, based on DF-generated daylighting availability from actual sky conditions

Modeling Capabilities (Near Term)

- Realistic buildings, to realistic levels of detail
- Quantitative interior surface luminance distributions
- Quantitative interior illuminance levels at any sensor point
- Daylight Factors

Modeling Capabilities (Near Term)

- Model realistic buildings, to realistic levels of detail
  - Arbitrarily-positioned rectangular surfaces
  - Windows and skylights
  - Complex Fenestration Systems (CFS)
  - Complex floor plans
  - Multiple lighting zones
  - Interior "contents": partitions, working surfaces, simple objects
  - Interior surface occlusion (patch-patch visibility)
  - Shading, occlusion by exterior objects

General Approach

- Stand-alone, single-sky-condition, integrated daylight - electric light modeler
- The DElight daylighting preprocessing calculation
- Whole building analysis integration

Stand-alone Single-sky-condition, Modeler

- Model the luminance distribution on all surfaces in the space by a radiosity method
- Outputs
  - Surface luminance distributions
  - Workplane illuminances

Daylighting Preprocessing

- For a sequence of external "standard sky" conditions
  - Model the luminance distribution on all surfaces in the space by a radiosity method
  - Determine the illuminance at defined (typically workplane) light sensor positions
  - Compute and store "Daylight Factors" (DF) at the sensor positions for individual light source components
- Outputs
  - Daylight Factors

Daylight Factors (DF)

- Separate daylight source components
  - overcast sky, clear sky, and clear sun
- Each component DF is the ratio of:
  - interior illuminance at a sensor position due to a particular component
  - the component horizontal EXTERIOR illuminance
- ASSUMPTION: This DF approach can accurately reconstitute an actual sensor illuminance from actual sky conditions
  - Depends on "reasonably smooth" exterior illuminance distribution from sky, exterior objects

Whole-Building Analysis Integration

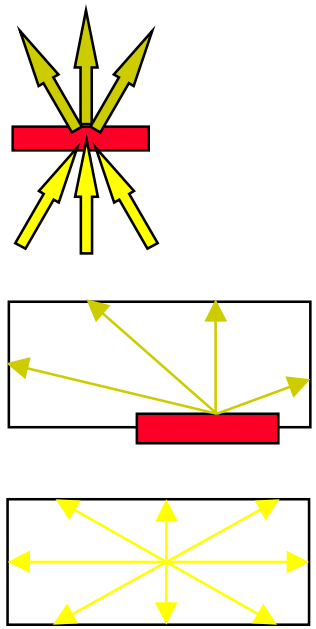
- For each sun-up time step in the thermal loop
  - Use weather tape sky conditions to
    - **determine the exterior illuminance for sky/sun components**
    - **determine clear sky / cloudy sky weighting factors**
  - Determine the sun position in the sky
  - Reconstitute the daylight illuminance at the sensor positions
    - **Interpolate the component DF, based on the actual sun position**
    - **Multiply by the associated actual exterior illuminance components**
  - Use the reconstituted illuminance values and a defined lighting control scheme to model the electric lighting
- Outputs
  - Required electric lighting levels
  - Lighting electricity requirements
  - Lighting heat-to-space

DElight Calculation Sequence

- Define and grid all surfaces based on building description
- Define an external sky condition
- Determine initial (or "direct") luminance distribution on all surfaces
- Determine the final (direct+interreflected) luminance distribution on all surfaces
- Determine illuminances for all sensor positions
- Calculate Daylight Factors for each sky/sun component for all sensor positions
- Repeat above sequence for a range of different sky conditions

Complex Fenestration Systems

- CFS Library
  - Bi-directional transmittance function (BTDF) characterization of CFS
- DElight Preprocessor
  - Direct luminance distribution
  - Interreflected luminance
  - Multiple sun position daylight factors
- DElight Time-Step Calculations
  - Interior illuminance at reference point
  - Electric light dimming to target total illuminance



Software Implementation

- ANSI C/C++ portable code
- Compiled as Windows 32-bit DLL
- Highly modular structure
- ASCII input/output files
- Annual hourly execution times on 300MHz Pentium:
  - Single zone, single aperture < 3 seconds
  - Five zone, fifty aperture < 5 seconds

DElight History, Origins

- Port of DOE-2 Daylight Analysis Algorithms
  - Existing algorithms
  - Fast execution times
  - Separate daylighting engine
  - Allows integration into thermal loops of any program
  - First used in ENERGY-10, AEDOT, BDA
- Enhancement from SUPERLITE and DOE-2 algorithms
  - Radiosity interreflection
  - Initial (or direct) distribution on surfaces
  - Targeted for ENERGY-10, EnergyPlus
- New Complex Fenestration System Analysis Methods
  - BTDF-based
  - IEA Task 21 connection

DElight Issues

- Validation
- DElight needs a long-term support, maintenance, and enhancement plan, commitment(s)
- DElight needs be portable for use in multiple tools
  - DLL aproach?
  - Formalized interoperability facilities
- The CFS characterization process needs to be "privatized"
  - Encourage market-driven efforts by product vendors
  - Quality-assurance issues need to be addressed through the development of standardized characterization and measurement methods
  - A standardized CFS library format needs to be developed
  - The CFS library needs to be expandable in a decentralized way by anyone

Potential Future Enhancements

- Non-rectangular surfaces, apertures
- Improved treatment of exterior surface luminances
  - specular surfaces, interreflection, occlusion
- Atria, interior apertures
- Adaptive surface meshing and progressive refinement radiosity solution
- Diagnostic imaging
  - Wireframe surfaces, patches
  - Surface luminance distributions
- Input file readers for .IFC, .RAD, .DXF building description files
- Color, IR modeling
- Quantitative characterizations of visual quality, comfort (e.g., glare), etc. in the interior space(s)
  - Both single-time-point and hourly
- Two-way DL/Lighting control integration
  - Fenestration control feedback